

FIG. 1

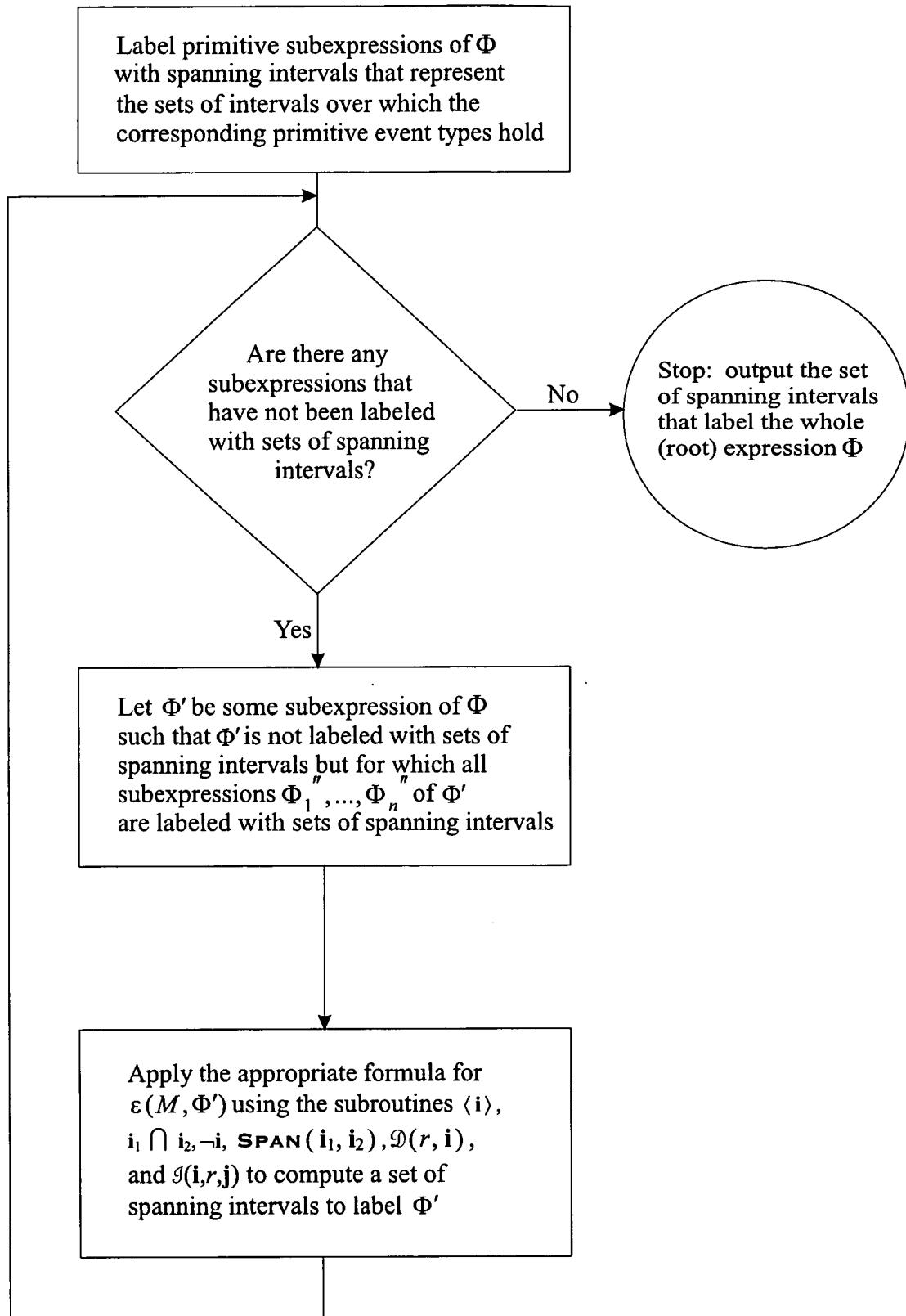


FIG. 2

$$\begin{aligned}
x = y &\triangleq \overline{x = y} \\
\text{SUPPORTED}(x) &\triangleq \overline{\neg \text{GROUNDED}(x)} \\
\text{RIGIDLYATTACHED}(x, y) &\triangleq \overline{(\exists r) \text{RIGID}(x, y, r)} \\
\text{SUPPORTS}(x, y) &\triangleq \overline{\left(\begin{array}{l} \neg \text{GROUNDED}(y) \wedge \\ \neg \text{STABLE}(P \setminus \{x\}, M \cup \{\text{GROUNDED}(z) \mid \neg \text{RIGIDLYATTACHED}^*(z, y)\}) \end{array} \right)} \\
\text{CONTACTS}(x, y) &\triangleq \overline{\text{TOUCHES}(x, y) \wedge x \bowtie y} \\
\text{ATTACHED}(x, y) &\triangleq \overline{(\exists r) \text{RIGID}(x, y, r) \vee \text{REVOLUTE}(x, y, r)}
\end{aligned}$$

FIG. 3

$$\begin{aligned}
\text{PICKUP}(x, y, z) &\triangleq \left\{ \begin{array}{l} \neg\Diamond x = y \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{SUPPORTED}(y) \wedge \neg\Diamond \text{ATTACHED}(x, z) \wedge \\ \left[\begin{array}{l} \neg\Diamond \text{ATTACHED}(x, y) \wedge \neg\Diamond \text{SUPPORTS}(x, y) \wedge \\ \text{SUPPORTS}(z, y) \wedge \\ \neg\Diamond \text{SUPPORTED}(x) \wedge \neg\Diamond \text{ATTACHED}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(y, x) \wedge \neg\Diamond \text{SUPPORTS}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(x, z) \wedge \neg\Diamond \text{SUPPORTS}(z, x) \end{array} \right]; \\ \left[\begin{array}{l} \text{ATTACHED}(x, y) \vee \text{ATTACHED}(y, z); \\ \text{ATTACHED}(x, y) \wedge \text{SUPPORTS}(x, y) \wedge \\ \neg\Diamond \text{SUPPORTS}(z, y) \wedge \\ \neg\Diamond \text{SUPPORTED}(x) \wedge \neg\Diamond \text{ATTACHED}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(y, x) \wedge \neg\Diamond \text{SUPPORTS}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(x, z) \wedge \neg\Diamond \text{SUPPORTS}(z, x) \end{array} \right] \end{array} \right\} \\
\text{PUTDOWN}(x, y, z) &\triangleq \left\{ \begin{array}{l} \neg\Diamond x = y \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{SUPPORTED}(y) \wedge \neg\Diamond \text{ATTACHED}(x, z) \wedge \\ \left[\begin{array}{l} \text{ATTACHED}(x, y) \wedge \text{SUPPORTS}(x, y) \wedge \\ \neg\Diamond \text{SUPPORTS}(z, y) \wedge \\ \neg\Diamond \text{SUPPORTED}(x) \wedge \neg\Diamond \text{ATTACHED}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(y, x) \wedge \neg\Diamond \text{SUPPORTS}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(x, z) \wedge \neg\Diamond \text{SUPPORTS}(z, x) \end{array} \right]; \\ \left[\begin{array}{l} \text{ATTACHED}(x, y) \vee \text{ATTACHED}(y, z); \\ \neg\Diamond \text{ATTACHED}(x, y) \wedge \neg\Diamond \text{SUPPORTS}(x, y) \wedge \\ \text{SUPPORTS}(z, y) \wedge \\ \neg\Diamond \text{SUPPORTED}(x) \wedge \neg\Diamond \text{ATTACHED}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(y, x) \wedge \neg\Diamond \text{SUPPORTS}(y, z) \wedge \\ \neg\Diamond \text{SUPPORTS}(x, z) \wedge \neg\Diamond \text{SUPPORTS}(z, x) \end{array} \right] \end{array} \right\} \\
\text{STACK}(w, x, y, z) &\triangleq \left[\begin{array}{l} \neg\Diamond z = w \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{PUTDOWN}(w, x, y) \wedge \text{SUPPORTS}(z, y) \wedge \neg\text{ATTACHED}(z, y) \end{array} \right] \\
\text{UNSTACK}(w, x, y, z) &\triangleq \left[\begin{array}{l} \neg\Diamond z = w \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{PICKUP}(w, x, y) \wedge \text{SUPPORTS}(z, y) \wedge \neg\text{ATTACHED}(z, y) \end{array} \right] \\
\text{MOVE}(w, x, y, z) &\triangleq \neg\Diamond y = z \wedge [\text{PICKUP}(w, x, y); \text{PUTDOWN}(w, x, z)] \\
\text{ASSEMBLE}(w, x, y, z) &\triangleq \text{PUTDOWN}(w, y, z) \wedge_{\{<\}} \text{STACK}(w, x, y, z) \\
\text{DISASSEMBLE}(w, x, y, z) &\triangleq \text{UNSTACK}(w, x, y, z) \wedge_{\{<\}} \text{PICKUP}(x, y, z)
\end{aligned}$$

FIG. 4

1990-02-20 09:00:00

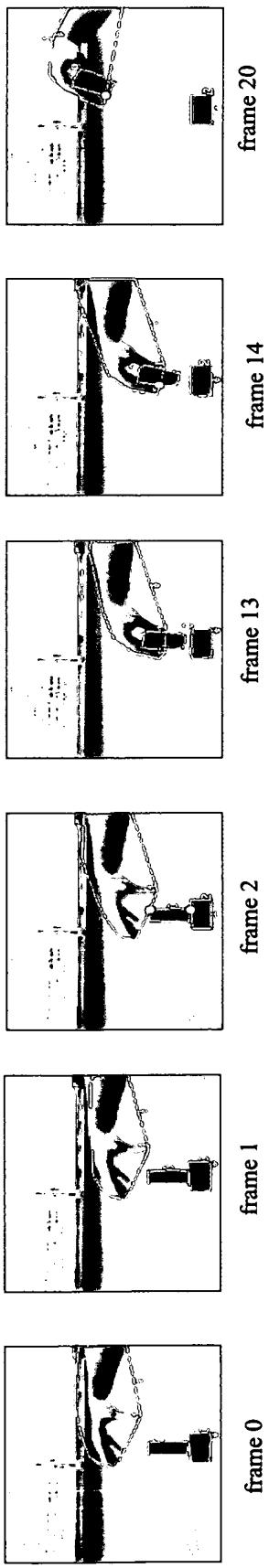


FIG. 5A

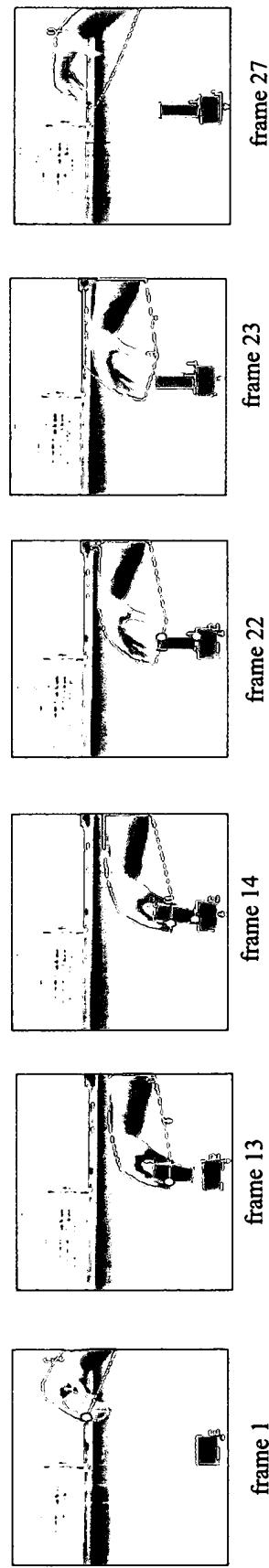


FIG. 5B

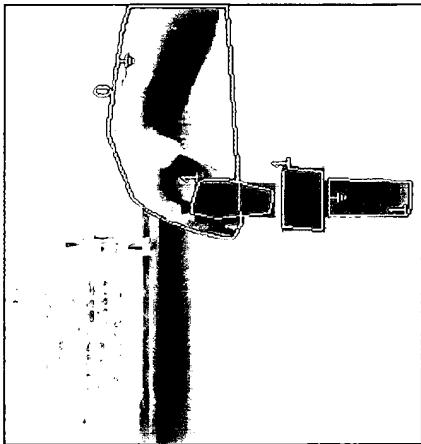
200945Z 24 03 022004

(PICK-UP MOVING RED GREEN)@{[[0,1],[14,22]]}
(SUPPORTED? RED)@{[[0:22]]}
(SUPPORTED? MOVING)@{[[1:13]], [[24:26]]}
(SUPPORTS? RED MOVING)@{[[1:13]], [[24:26]]}
(SUPPORTS? MOVING RED)@{[[13:22]]}
(SUPPORTS? GREEN RED)@{[[0:14]]}
(SUPPORTS? GREEN MOVING)@{[[1:13]]}
(CONTACTS? RED GREEN)@{[[0:2]], [[6:14]]}
(ATTACHED? RED MOVING)@{[[1:26]]}
(ATTACHED? RED GREEN)@{[[1:6]]}

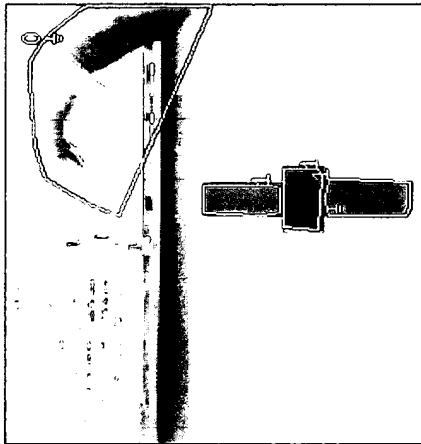
(PUT-DOWN MOVING RED GREEN)@{[[0,14],[23,32]]}
(SUPPORTED? MOVING)@{[[14:23]]}
(SUPPORTED? RED)@{[[0:32]]}
(SUPPORTS? MOVING RED)@{[[0:14]]}
(SUPPORTS? RED MOVING)@{[[14:23]]}
(SUPPORTS? GREEN MOVING)@{[[14:23]]}
(SUPPORTS? GREEN RED)@{[[14:32]]}
(CONTACTS? RED GREEN)@{[[22:32]]}
(ATTACHED? MOVING RED)@{[[0:23]]}
(ATTACHED? RED GREEN)@{[[14:22]]}

FIG. 6A

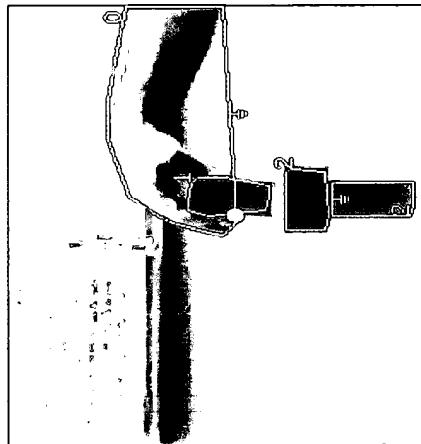
FIG. 6B



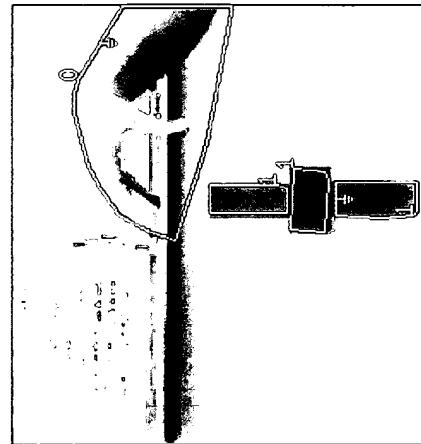
frame 12



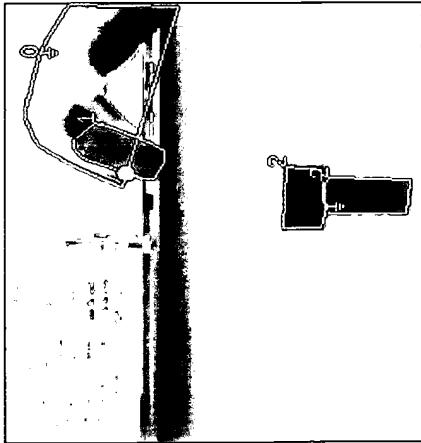
frame 26



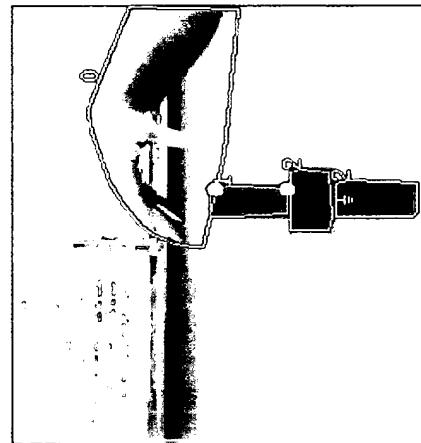
frame 11



frame 24

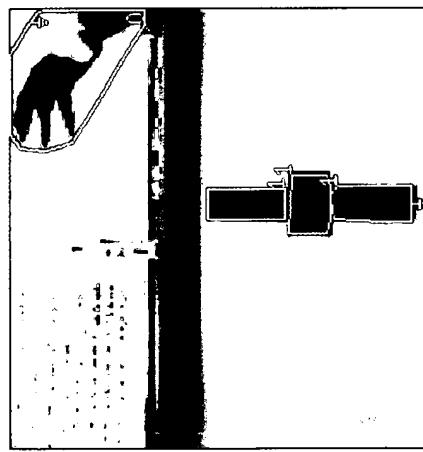


frame 3

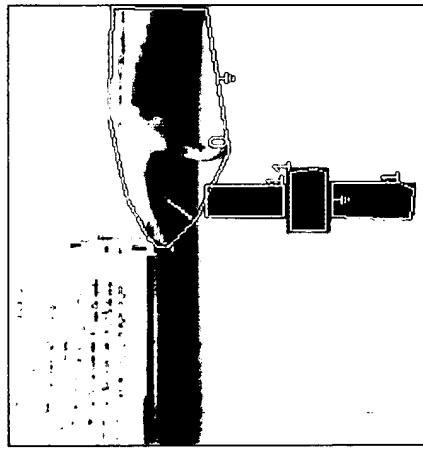


frame 23

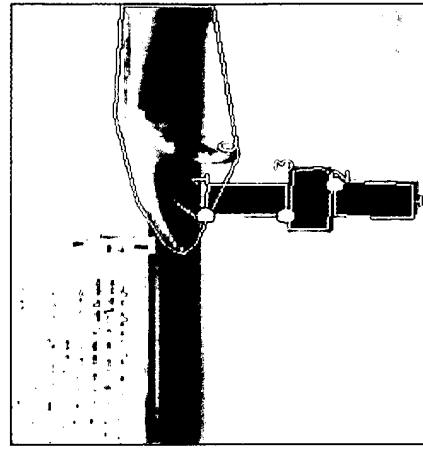
FIG. 7A



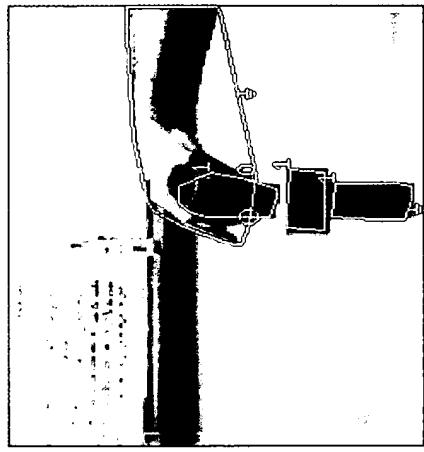
frame 1



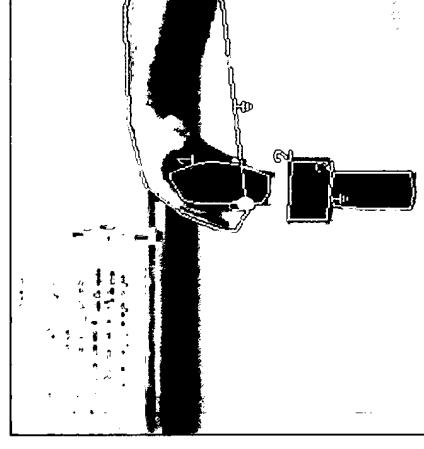
frame 10



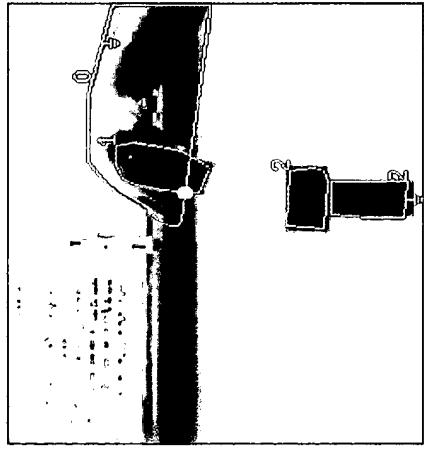
frame 11



frame 24

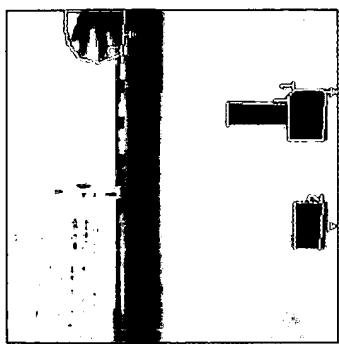


frame 25

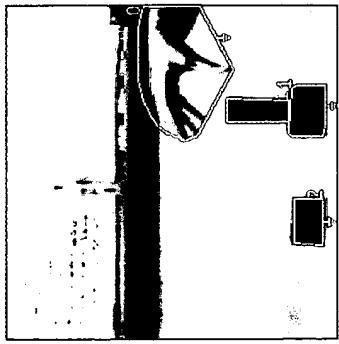


frame 29

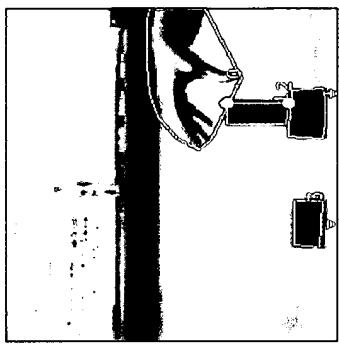
FIG. 7B



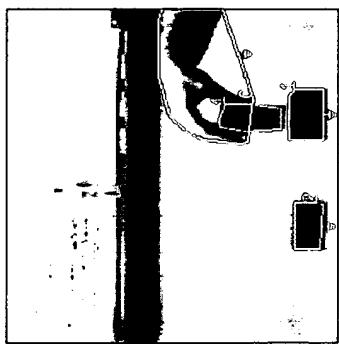
frame 0



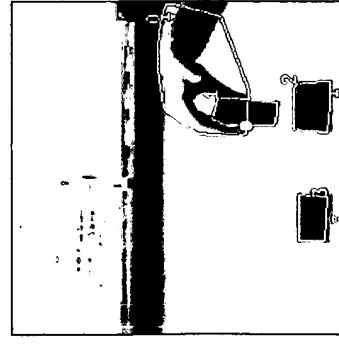
frame 8



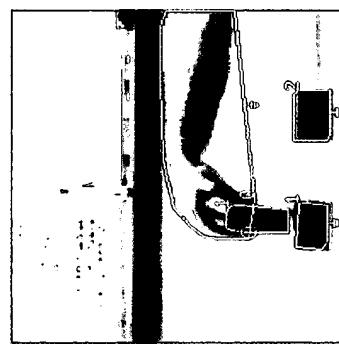
frame 9



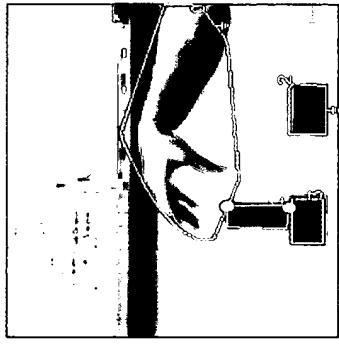
frame 16



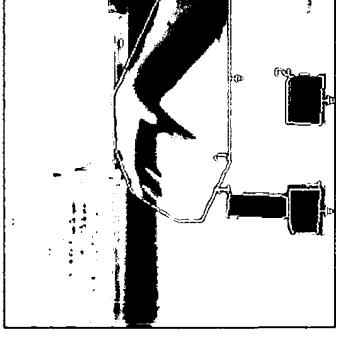
frame 17



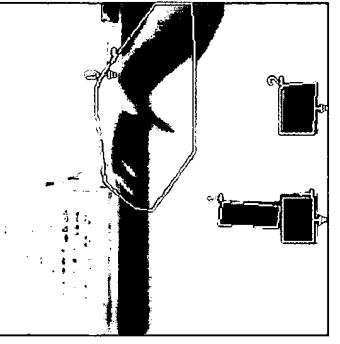
frame 33



frame 45



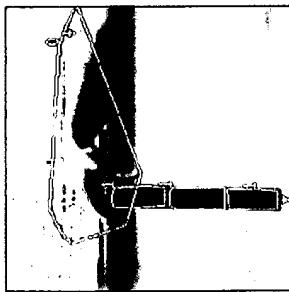
frame 46



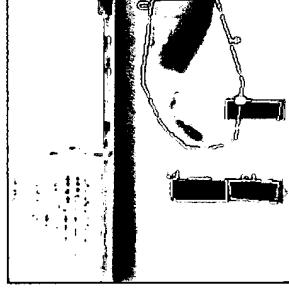
frame 47

FIG. 7C

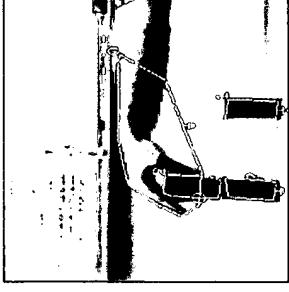




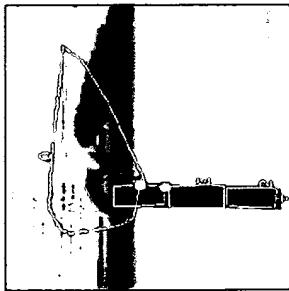
frame 18



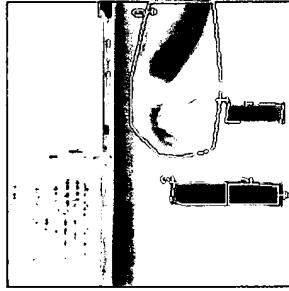
frame 49



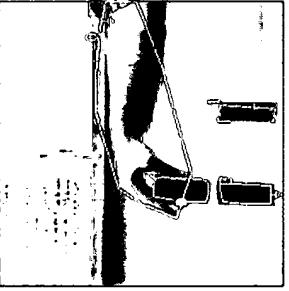
frame 62



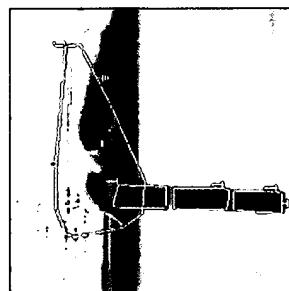
frame 19



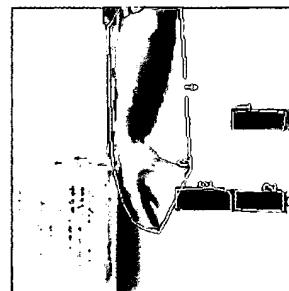
frame 50



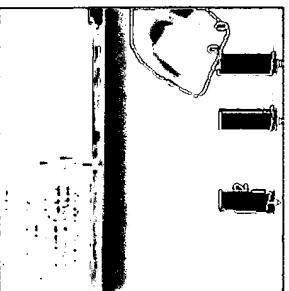
frame 63



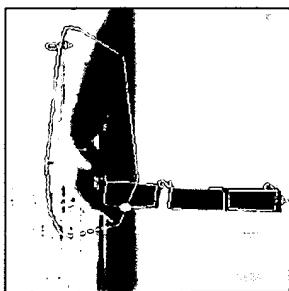
frame 22



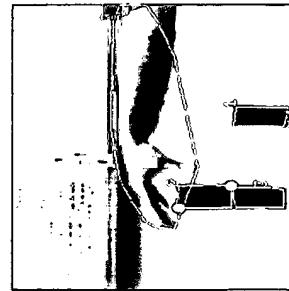
frame 56



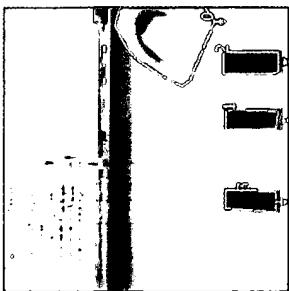
frame 87



frame 18



frame 23



frame 57

FIG. 7E

```

(PUT-DOWN MOVING RED BLUE)@(([0,12],[24,30]))
(STACK MOVING RED BLUE GREEN)@(([0,12],[24,30]))

(SUPPORTED? MOVING)@(([13:24]))
(SUPPORTED? RED)@(([0:30]))
(SUPPORTED? BLUE)@(([0:30]))
(SUPPORTS? MOVING RED)@(([0:12]))
(SUPPORTS? RED MOVING)@(([13:24]))
(SUPPORTS? RED BLUE)@(([19:20]), ([21:22]))
(SUPPORTS? GREEN MOVING)@(([19:20]), ([21:22]))
(SUPPORTS? GREEN RED)@(([19:20]), ([21:22]))
(SUPPORTS? GREEN BLUE)@(([0:30]))
(SUPPORTS? BLUE MOVING)@(([13:24]))
(SUPPORTS? BLUE RED)@(([12:30]))
(CONTACTS? RED BLUE)@(([12:19]), ([20:21]), ([22:30]))
(CONTACTS? GREEN BLUE)@(([0:30]))
(ATTACHED? MOVING RED)@(([0:24]))
(ATTACHED? RED BLUE)@(([19:20]), ([21:22]))

```

FIG. 8A

```

(PICK-UP MOVING RED BLUE)@(([0,11],[25,33]))
(UNSTACK MOVING RED BLUE GREEN)@(([0,11],[25,33]))

(SUPPORTED? MOVING)@(([11:23]))
(SUPPORTED? RED)@(([0:36]))
(SUPPORTED? BLUE)@(([0:36]))
(SUPPORTS? MOVING RED)@(([23:36]))
(SUPPORTS? RED MOVING)@(([11:23]))
(SUPPORTS? RED BLUE)@(([13:14]))
(SUPPORTS? GREEN MOVING)@(([13:14]))
(SUPPORTS? GREEN RED)@(([13:14]))
(SUPPORTS? GREEN BLUE)@(([0:36]))
(SUPPORTS? BLUE MOVING)@(([11:23]))
(SUPPORTS? BLUE RED)@(([0:25]))
(CONTACTS? MOVING RED)@(([34:36]))
(CONTACTS? RED BLUE)@(([0:13]), ([14:24]))
(CONTACTS? GREEN BLUE)@(([0:13]), ([14:36]))
(ATTACHED? MOVING RED)@(([11:33]))
(ATTACHED? RED BLUE)@(([13:14]))
(ATTACHED? GREEN BLUE)@(([13:14]))

```

FIG. 8B

```

(PICK-UP MOVING RED GREEN)@(([0,9],[17,46]))
(PUT-DOWN MOVING RED BLUE)@(([17,35],[46,52]))
(MOVE MOVING RED GREEN BLUE)@(([0,9],[46,52]))

(SUPPORTED? MOVING)@(([9:15]))
(SUPPORTED? RED)@(([0:52]))
(SUPPORTED? BLUE)@(([35:46]))
(SUPPORTS? MOVING RED)@(([17:46]))
(SUPPORTS? MOVING BLUE)@(([35:46]))
(SUPPORTS? RED MOVING)@(([9:15]))
(SUPPORTS? RED BLUE)@(([35:46]))
(SUPPORTS? GREEN MOVING)@(([9:15]))
(SUPPORTS? GREEN RED)@(([0:17]))
(SUPPORTS? BLUE RED)@(([46:52]))
(CONTACTS? RED GREEN)@(([0:17]))
(CONTACTS? RED BLUE)@(([46:52]))
(ATTACHED? MOVING RED)@(([9:46]))
(ATTACHED? RED BLUE)@(([35:46]))

```

FIG. 8C

```

(PUT-DOWN MOVING RED GREEN)@(([57,68],[68,87]))
(PUT-DOWN MOVING GREEN BLUE)@(([18,35],[41,47]))
(STACK MOVING RED GREEN BLUE)@(([57,68],[68,87]))
(ASSEMBLE MOVING RED GREEN BLUE)@(([18,35],[68,87]))

(SUPPORTED? MOVING)@(([10:18]), ([47:57]))
(SUPPORTED? RED)@(([57:87]))
(SUPPORTED? GREEN)@(([11:87]))
(SUPPORTED? BLUE)@(([35:41]))
(SUPPORTS? MOVING RED)@(([57:68]))
(SUPPORTS? MOVING GREEN)@(([11:41]))
(SUPPORTS? MOVING BLUE)@(([35:41]))
(SUPPORTS? RED MOVING)@(([10:18]), ([47:57]))
(SUPPORTS? RED GREEN)@(([11:16]))
(SUPPORTS? GREEN RED)@(([68:87]))
(SUPPORTS? GREEN BLUE)@(([35:41]))
(SUPPORTS? BLUE GREEN)@(([41:87]))
(CONTACTS? RED GREEN)@(([68:87]))
(CONTACTS? GREEN BLUE)@(([41:87]))
(ATTACHED? MOVING RED)@(([11:16]), ([49:68]))
(ATTACHED? MOVING GREEN)@(([11:41]))
(ATTACHED? GREEN BLUE)@(([35:41]))

```

FIG. 8D

```

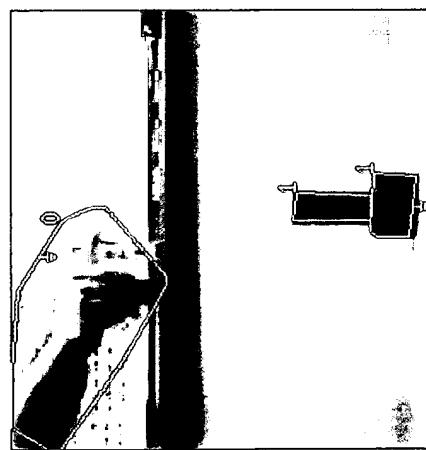
(PICK-UP MOVING RED GREEN)@(([0,19],[23,50]))
(PICK-UP MOVING GREEN BLUE)@(([22,58],[62,87]))
(UNSTACK MOVING RED GREEN BLUE)@(([0,19],[23,50]))
(DISASSEMBLE MOVING RED GREEN BLUE)@(([0,19],[62,87]))

(SUPPORTED? MOVING)@(([19:22]))
(SUPPORTED? RED)@(([0:50]))
(SUPPORTED? GREEN)@(([0:87]))
(SUPPORTED? BLUE)@(([58:62]))
(SUPPORTS? MOVING RED)@(([23:50]))
(SUPPORTS? MOVING GREEN)@(([58:87]))
(SUPPORTS? MOVING BLUE)@(([58:62]))
(SUPPORTS? RED MOVING)@(([19:22]))
(SUPPORTS? GREEN MOVING)@(([19:22]))
(SUPPORTS? GREEN RED)@(([0:23]))
(SUPPORTS? GREEN BLUE)@(([58:62]))
(SUPPORTS? BLUE GREEN)@(([0:58]))
(CONTACTS? RED GREEN)@(([0:23]))
(CONTACTS? GREEN BLUE)@(([0:58]))
(ATTACHED? MOVING RED)@(([19:50]))
(ATTACHED? MOVING GREEN)@(([58:87]))
(ATTACHED? GREEN BLUE)@(([58:62]))

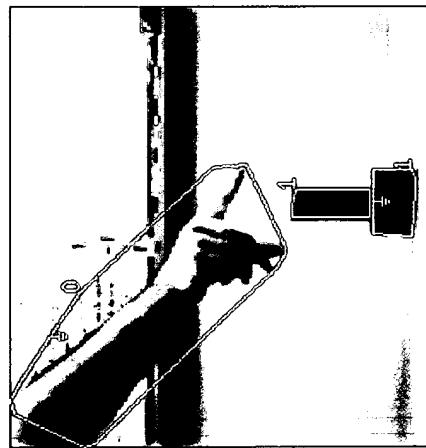
```

FIG. 8E

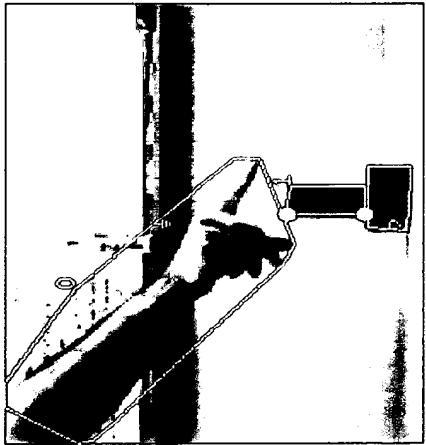
FIGURE 9 "G" FIGURE 9A



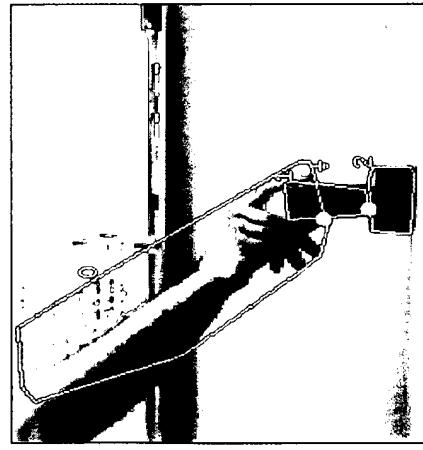
frame 5



frame 10



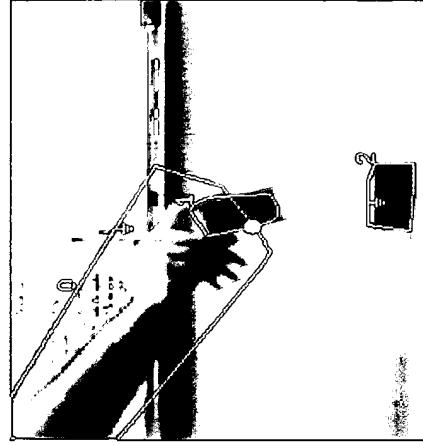
frame 11



frame 17



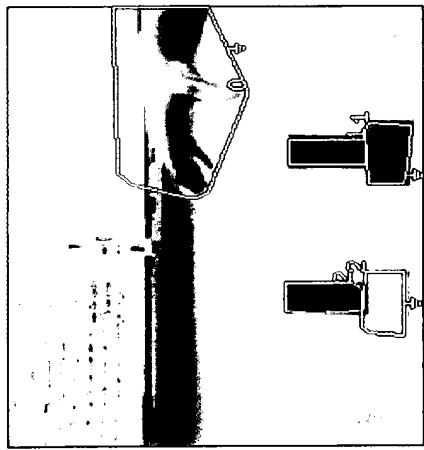
frame 18



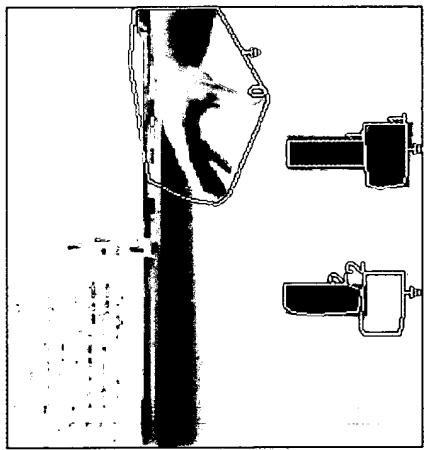
frame 22

FIG. 9A

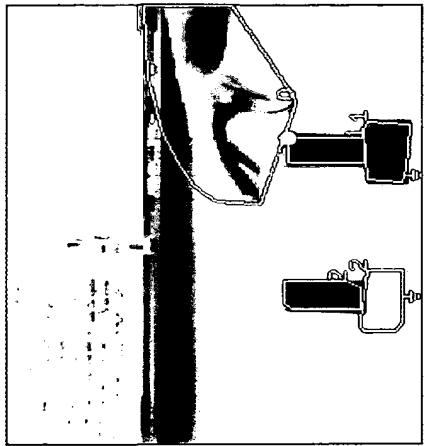
FIGURE 9B - FIGURE 9B



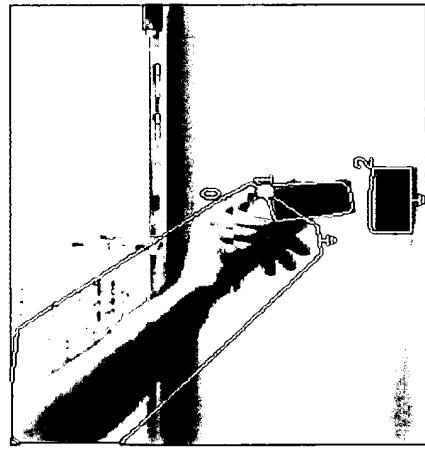
frame 6



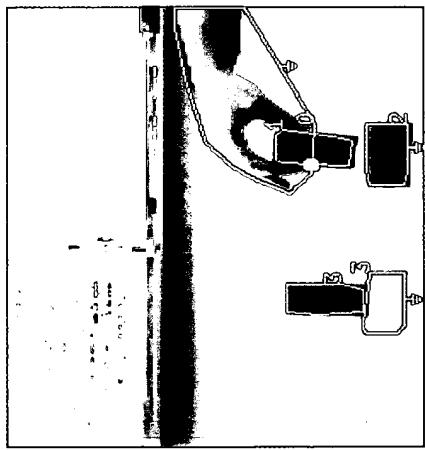
frame 7



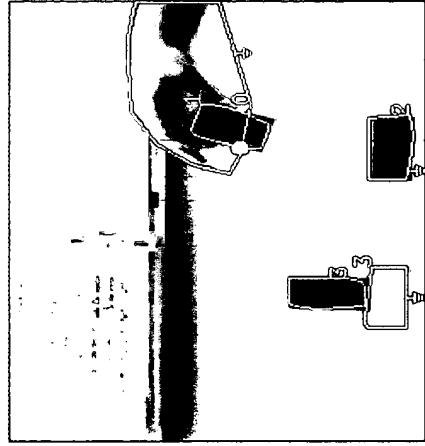
frame 8



frame 18



frame 19



frame 24

FIG. 9B

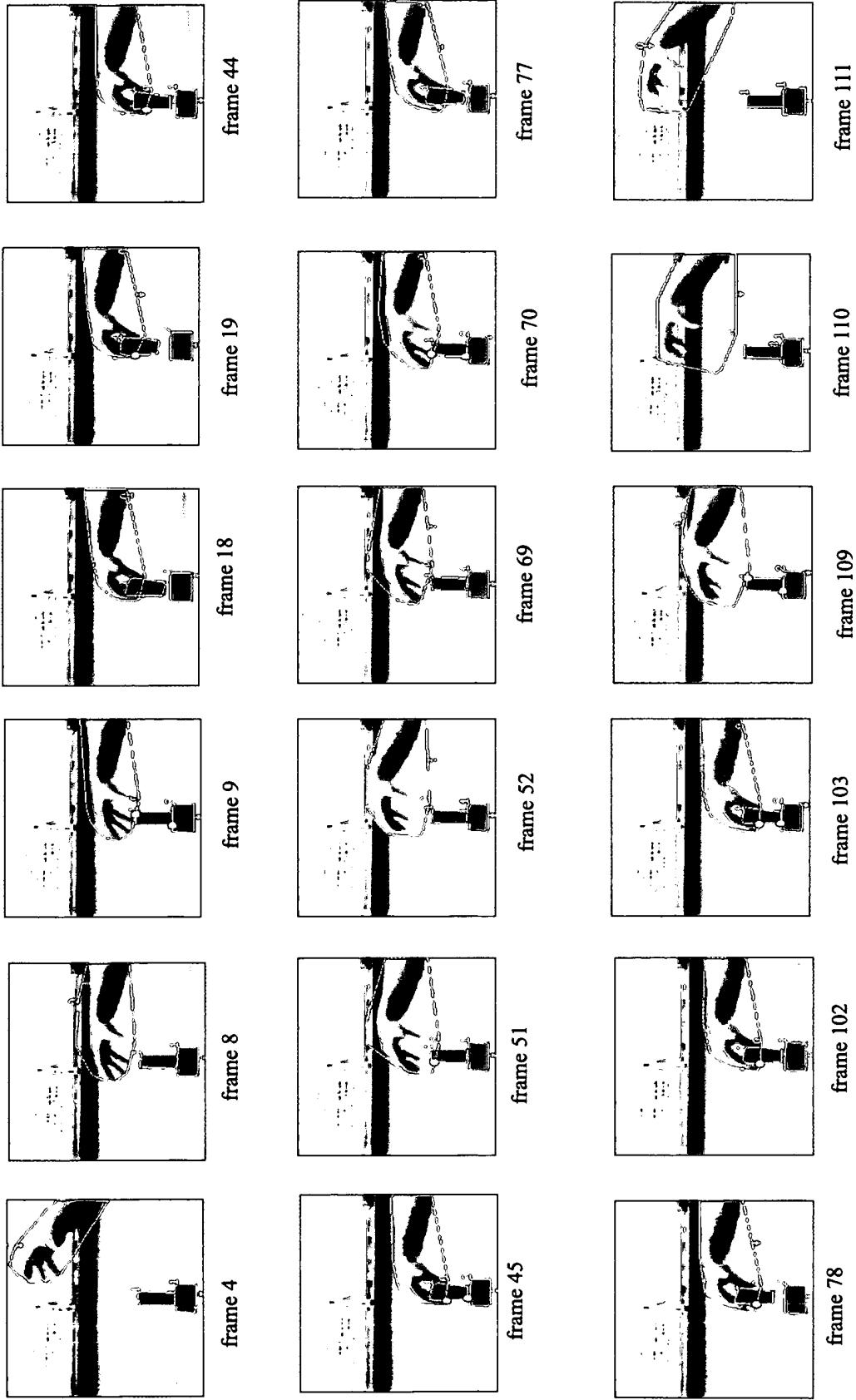
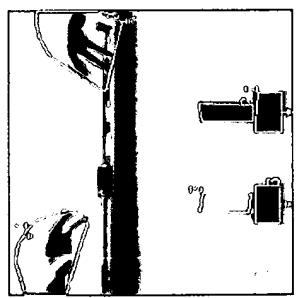
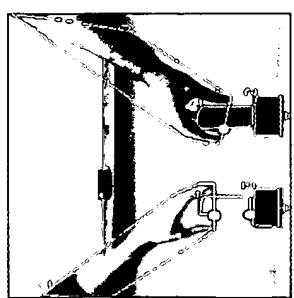


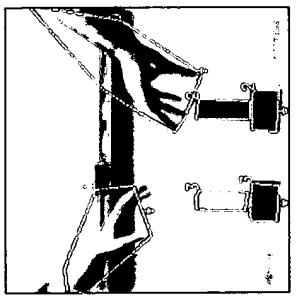
FIG. 9C



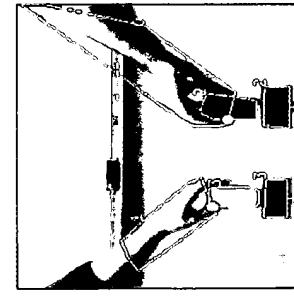
frame 0



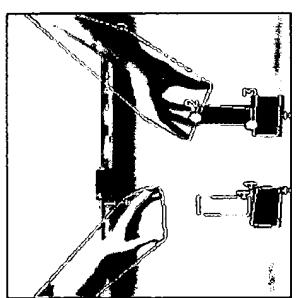
frame 11



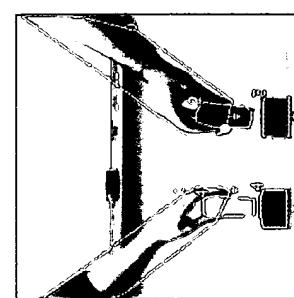
frame 5



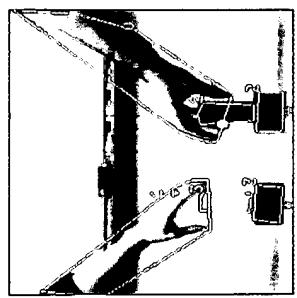
frame 15



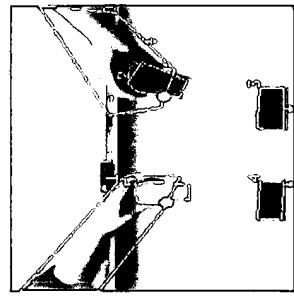
frame 6



frame 16



frame 10



frame 21

FIG. 9D

```

(PICK-UP MOVING RED GREEN)@([[0,11],[18,30]])
(SUPPORTED? RED)@([[0:30]])
(SUPPORTED? GREEN)@([[11:18]])
(SUPPORTS? MOVING RED)@([[11:30]])
(SUPPORTS? MOVING GREEN)@([[11:18]])
(SUPPORTS? RED GREEN)@([[11:18]])
(SUPPORTS? GREEN RED)@([[0:11]])
(CONTACTS? RED GREEN)@([[0:11]])
(ATTACHED? MOVING RED)@([[11:30]])
(ATTACHED? RED GREEN)@([[11:18]])

```

FIG. 10A

```

(PICK-UP MOVING RED GREEN)@([[0,8],[19,30]])
(SUPPORTED? MOVING)@([[8:19]])
(SUPPORTED? RED)@([[0:30]])
(SUPPORTED? BLUE)@([[0:30]])
(SUPPORTS? MOVING RED)@([[19:30]])
(SUPPORTS? RED MOVING)@([[8:19]])
(SUPPORTS? GREEN MOVING)@([[8:19]])
(SUPPORTS? GREEN RED)@([[0:19]])
(SUPPORTS? YELLOW BLUE)@([[0:30]])
(CONTACTS? RED GREEN)@([[0:10],[16:19]])
(CONTACTS? BLUE YELLOW)@([[0:30]])
(ATTACHED? MOVING RED)@([[8:30]])
(ATTACHED? RED GREEN)@([[10:16]])

```

FIG. 10B

```

(PICK-UP MOVING RED GREEN)@([[52,70],[78,102]), [[0,9],[19,44]])
(PUT-DOWN MOVING RED GREEN)@([[19,44],[52,70]), [[78,102],[110,117]])
(SUPPORTED? MOVING)@([[9:18]), [[44:52]), [[70:77]), [[102:110]])
(SUPPORTED? RED)@([[0:117]])
(SUPPORTS? MOVING RED)@([[18:44]), [[78:102]])
(SUPPORTS? RED MOVING)@([[9:18]), [[44:52]), [[70:77]), [[102:110]])
(SUPPORTS? GREEN MOVING)@([[9:18]), [[44:52]), [[70:77]), [[102:110]])
(SUPPORTS? GREEN RED)@([[0:19]), [[44:78]), [[102:117]])
(CONTACTS? RED GREEN)@([[0:9]), [[13:18]), [[46:70]), [[106:117]])
(ATTACHED? MOVING RED)@([[9:52]), [[70:110]])
(ATTACHED? RED GREEN)@([[9:13]), [[70:76]), [[104:106]])

```

FIG. 10C

```

(PICK-UP MOVING RED GREEN)@([[0,6],[16,22]])
(PICK-UP MOVING YELLOW BLUE)@([[0,12],[17,22]])
(SUPPORTED? MOVING)@([[6:16]])
(SUPPORTED? MOVING)@([[12:15]])
(SUPPORTED? RED)@([[0:22]])
(SUPPORTED? YELLOW)@([[0:22]])
(SUPPORTS? MOVING RED)@([[16:22]])
(SUPPORTS? MOVING YELLOW)@([[17:22]])
(SUPPORTS? RED MOVING)@([[6:16]])
(SUPPORTS? GREEN MOVING)@([[6:16]])
(SUPPORTS? GREEN RED)@([[0:16]])
(SUPPORTS? BLUE MOVING)@([[12:15]])
(SUPPORTS? BLUE YELLOW)@([[0:17]])
(SUPPORTS? YELLOW MOVING)@([[12:15]])
(CONTACTS? RED GREEN)@([[0:15]])
(CONTACTS? BLUE YELLOW)@([[0:17]])
(ATTACHED? MOVING RED)@([[6:22]])
(ATTACHED? MOVING YELLOW)@([[12:22]])

```

FIG. 10D

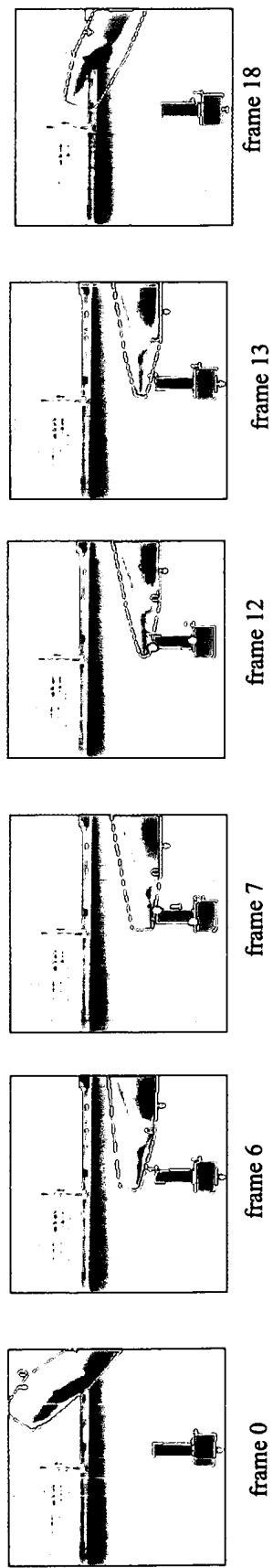


FIG. 11A

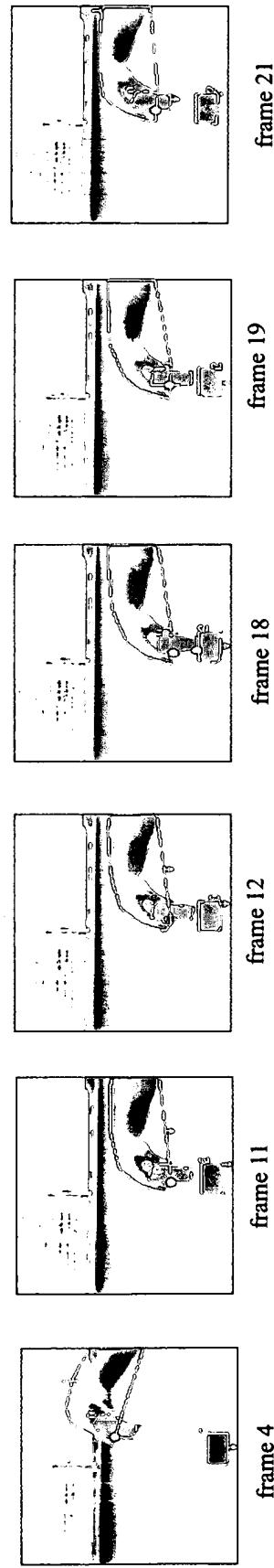


FIG. 11B

```
(SUPPORTED? RED)@{[[0:25]])
(SUPPORTED? GREEN)@{[[7:13]])
(SUPPORTS? MOVING RED)@{[[7:13]])
(SUPPORTS? MOVING GREEN)@{[[7:13]])
(SUPPORTS? RED GREEN)@{[[7:13]])
(SUPPORTS? GREEN RED)@{[[0:7]], [[13:25]])
(CONTACTS? RED GREEN)@{[[0:7]], [[13:25]])
(ATTACHED? MOVING RED)@{[[7:13]])
(ATTACHED? RED GREEN)@{[[7:13]]}
```

```
(SUPPORTED? RED)@{[[0:19]]}
(SUPPORTED? MOVING)@{[[13:31]]}
(SUPPORTS? RED MOVING)@{[[13:31]]}
(SUPPORTS? MOVING RED)@{[[0:13]]}
(SUPPORTS? GREEN RED)@{[[12:19]]}
(SUPPORTS? GREEN MOVING)@{[[13:19]]}
(ATTACHED? RED MOVING)@{[[0:31]]}
(ATTACHED? RED GREEN)@{[[13:19]]}
```

FIG. 12A

FIG. 12B